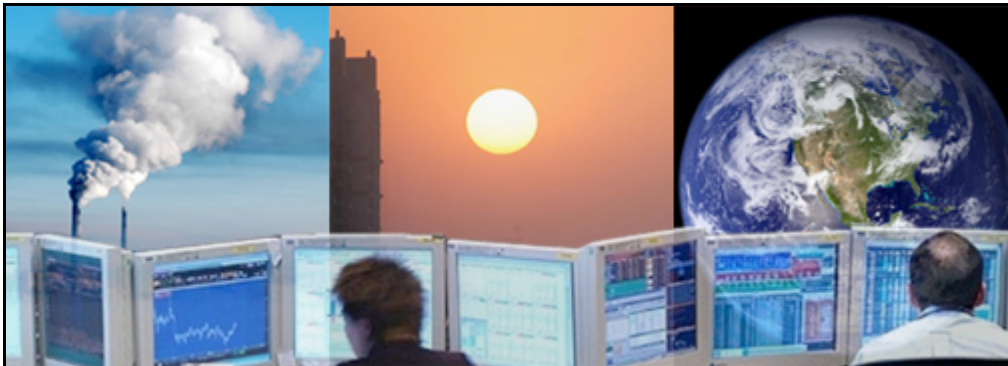


Presents

Carbon Pricing and the Transition from Voluntary to Mandatory Markets



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I. **Executive Summary**

The current national and global call for a coordinated and meaningful response to climate change concerns is certain to shift the United States from several regional and voluntary carbon markets today to a global compulsory market in the near future. In addition to the clear environmental benefits, this changing landscape will result in groups of carbon market "winners" and "losers" – some market segments will gain favor and market share while others will lose economic opportunity.

The competitive disadvantage for traditional energy in a carbon-priced world will be a catalyst for market-driven innovations in renewable energy, and sustainable development¹. Financial markets, specific investment banks, insurance underwriters, and emerging carbon finance corporations will be among the players who will benefit and monetize this transitional market. New carbon-linked products and services have already emerged globally in both voluntary and mandatory markets.

There are many opportunities where Austin and Texas stand to gain as larger carbon pricing components are realized. Renewable energy technology and project development will obviously benefit. Technologies that improve the conversion efficiency of hydrocarbons in the power generation, fuels, and industrial sectors will also grow. Energy efficiency and smart grid technologies will be more aggressively adopted providing a boost to the tech sectors of Texas. However, Texas needs to innovate and invest ahead of a mandatory carbon market if it intends to be a future energy leader.

This primer looks to explore the political, economic, and design considerations that will affect the development of the carbon market.

II. Why Price Carbon Dioxide?

There is little scientific debate that the consequences of global warming, if left unchecked, will be severe, both to the health of our ecosystem, and to our global economy. There is also sound scientific evidence that global temperatures have risen in the 20th century. What was hotly debated until recently was the effect that the additional greenhouse gases (measured in terms of “Carbon Dioxide Equivalent” or CO₂e) have on global temperature and sea levels. Some skeptics still believe that the temperature changes are caused by natural variance in the earth’s climate (solar forcing), and that it is indeterminable what effect human activity has had on global temperatures and sea levels.

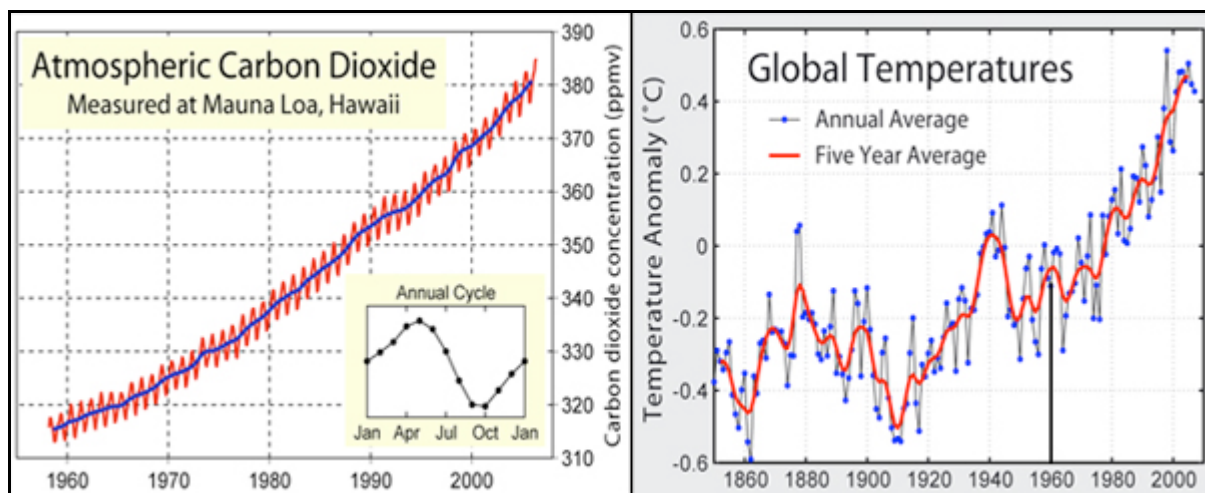


Figure 1: Left: Mauna Loa Observatory (2003), Right: IEA; EPA; WRI; UNFCCC; McKinsey (Dec, 07)

Figure 1 above shows the strong correlation between the increasing concentrations of CO₂e in the atmosphere and rising global temperatures. Currently, carbon dioxide contributes 92.6% of the total greenhouse gases in the earth’s atmosphere. Carbon dioxide transmits visible light, but absorbs infrared light, thereby increasing the temperature of the atmosphere. Carbon dioxide levels have risen from roughly 200 parts-per-million (ppm) in 1960 to 383 ppm in 2008. A December, 2007 McKinsey report estimates that, if left unchecked, annual greenhouse gas emissions will increase from 7.2 gigatons of CO₂e to 9.7 gigatons by 2030. In 2005, The U.S. National Academy of Sciences stated: “the scientific understanding of climate change is now sufficiently clear to justify nations taking prompt actions.”

In 2007, the Intergovernmental Panel on Climate Change (IPCC), a division of the World Meteorological Organization (WMO) was awarded the Nobel Peace Prize for its objective climate change report which concluded that anthropogenic (human-activity) CO₂e was a leading cause of global warming (see Figure 2 below). The influence this report has had on corporations world-wide is evident from the growing number of Fortune 500 companies that are now

members of the U.S. Climate Action Partnership, including many of the major oil and gas companies and manufacturing firms that will be negatively affected by carbon pricing.

The majority of the scientific and business community has settled on a cause of global warming that can be controlled; now the question on everyone's mind is how to best address the issue. The solution that has emerged is to use market forces to wean our economy off emissions-heavy technologies and fuel sources.

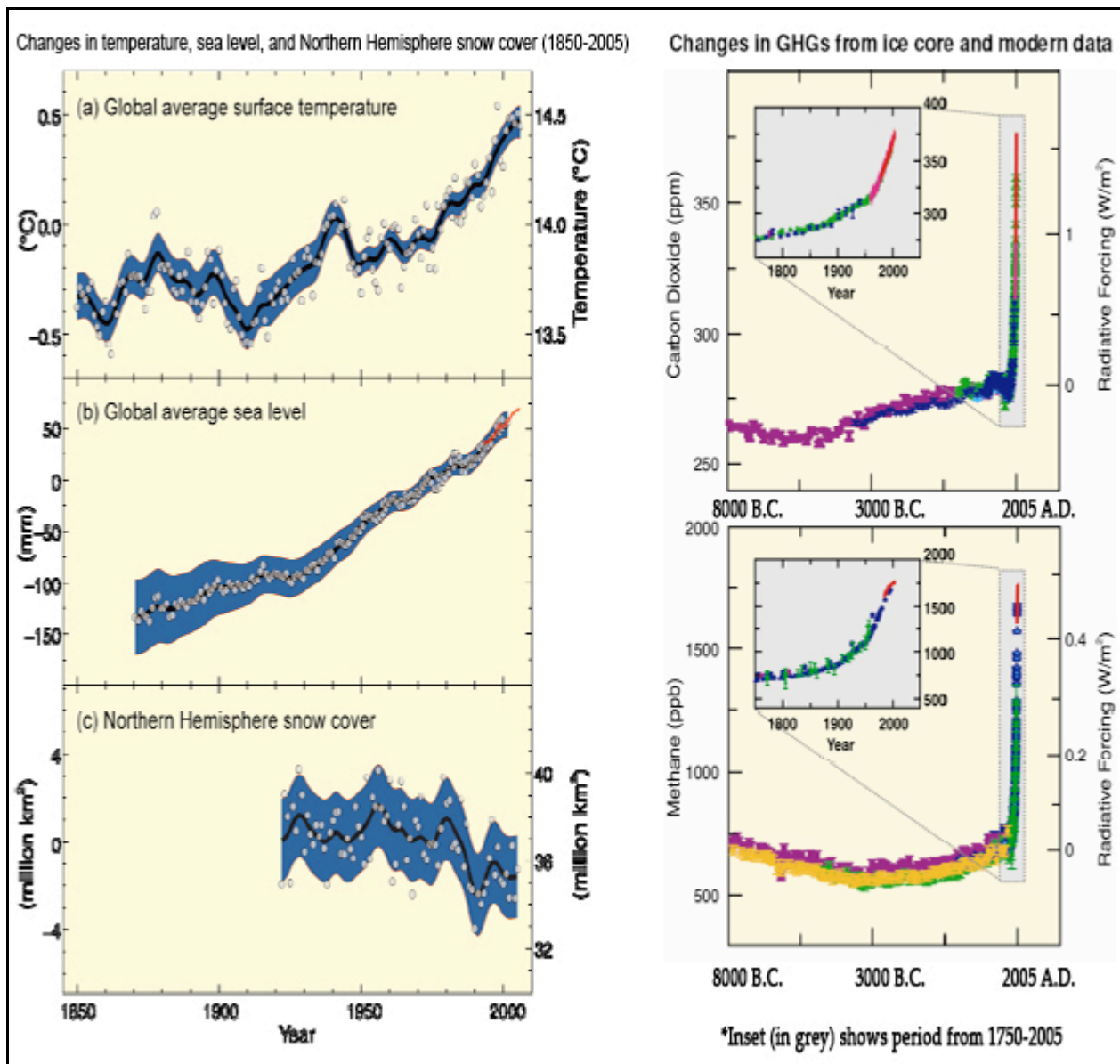


Figure 2: Shows increasing global temperatures and sea levels and correlated increases in levels of carbon dioxide and methane in the atmosphere - Left: IPCC AR4 - Topic 1 (2007), Right: IPCC AR4 – Topic 2 (2007)ⁱⁱ

III. Greenhouse Gas (GHG) Emissions Summarized

To understand the carbon market and its potential economic impacts, it is important to first identify the major greenhouse gases (GHGs), determine what quantities (tons CO₂e) are being emitted, and establish the relative impact each gas has on global warming. A visual summarization of IPCC's global GHG analysis is shown below in Figure 3. It shows the major greenhouse gases: carbon dioxide, methane (CH₄), nitrous oxide (N₂O), and fluorinated gases (F-gases). The bottom-right corner of Figure 3 shows various economic sectors and the percentage of GHG emissions they are generating.

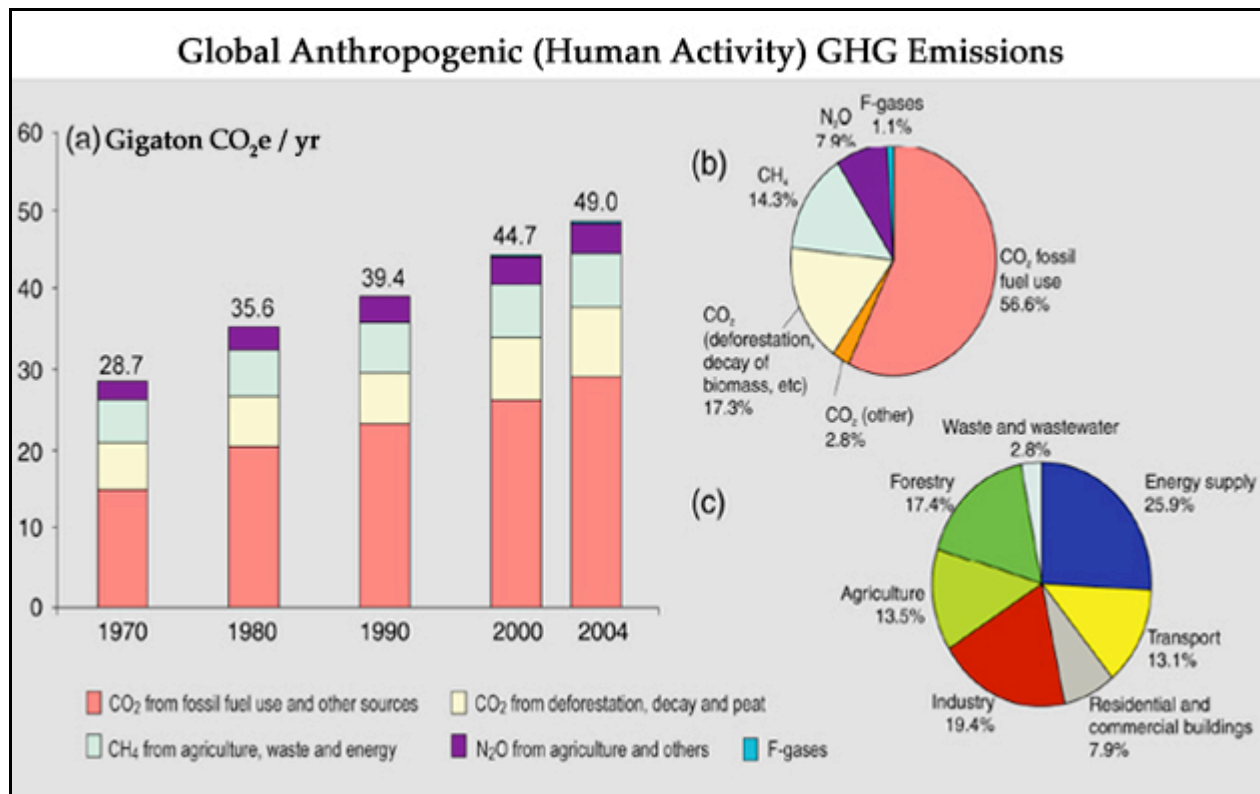


Figure 3: Breakdown of global GHG gases by % of total and by economic sector - Climate Change: 2007 Synthesis Report, IPCCⁱⁱⁱ

Drilling down from the global GHG statistics to the U.S. GHG figures, the data shows that a majority of GHG emissions come from primarily two sectors of our economy.

1. Transportation
2. Electricity Generation

Fossil-fuels (petroleum used in transportation and coal in electricity generation) produce the largest percentage of emissions (see Figure 4 below). These two sectors have the highest

economic exposure to carbon pricing, and will be the focus of our analysis. This is not to discount the importance of the demand side of the energy equation. Energy-intensive “end-user” sectors of the economy indirectly account for the majority of GHG emissions (see Figure 4 below). For example, commercial and residential buildings indirectly account for 45% of U.S. GHG emissions through the energy they consume. The Energy Information Association (EIA) branch of the DoE believes that manufacturing industries such as: chemicals and allied products; stone, clay, glass, concrete, and primary metals also have significant exposure to carbon pricing because of their relative energy intensity.^{iv}

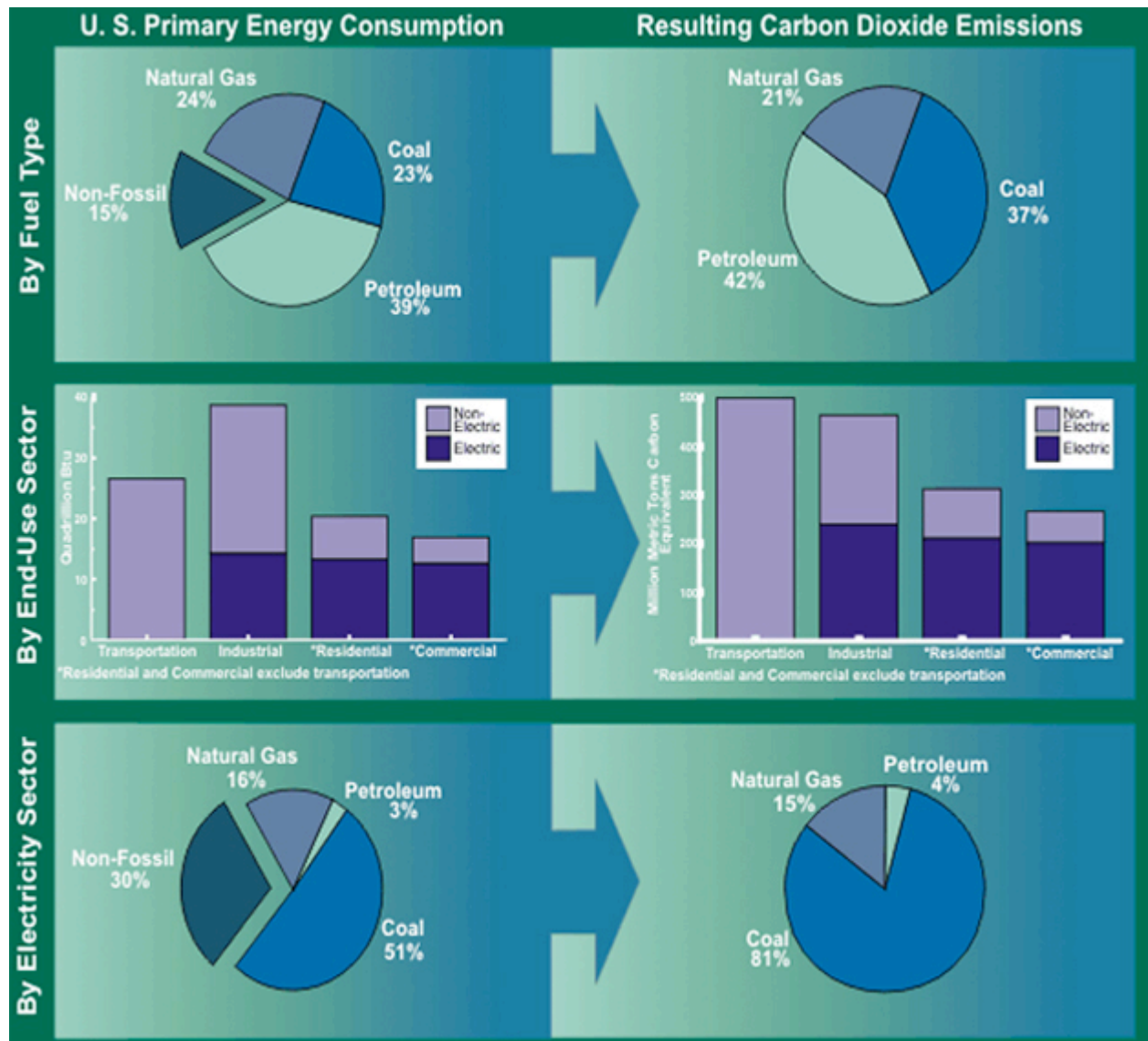


Figure 4: Breakdown of U.S. power consumption and GHGs by economic sector-, EIA^v

IV. **Carbon Pricing and the Economic Impacts**

In March of 2001, the Bush administration officially rejected the Kyoto Protocol, citing the economic hardship the U.S. would suffer if pressed to reduce greenhouse gas emissions under Kyoto's timetable and the wrongful exclusion of developing nations from the accord. In a March, 2001 letter to several U.S. senators, President Bush explained his position that Kyoto would result in a dramatic shift from coal to natural gas for electricity production which would lead to significant price increases for consumers. In the last seven years, the political pendulum has swung in the other direction. Many companies participate in a voluntary carbon market arrangement, while states in the West, Northeast and Midwest are setting up mandatory markets. Twenty-five states have enacted Renewable Portfolio Standards (RPS) to spur development of renewable energy. For the first time, the 2008 presidential front-runners of both parties support a federal cap & trade system for CO₂e.

As the U.S. is poised to enact a carbon cap & trade scheme, it is important to understand the debate of carbon tax vs. carbon cap & trade, and to evaluate the positive and negative impacts that carbon pricing will have at all levels of our economy.

Solutions – Cap & Trade vs. Carbon Tax

Under a cap & trade scheme, a central authority (the DoE or EPA, if a mandatory scheme is set up by the Federal Government) decides how much CO₂e may be emitted (the cap), and issues allowances for that amount. It may issue the allowances free of charge to pollution emitters such as electricity generators, or it may auction some or all of them. However they are issued, the allowances may then be freely traded between market participants. It would not be practical to deal with transportation emissions by issuing allowances to individual drivers, but they could instead be issued to refiners or petroleum products importers. These cap & trade design considerations, and others will be discussed in detail in section V of this report.

Proponents of a carbon tax solution argue that free-allocation is a form of corporate welfare, and that freely distributing some percentage of allowances to the heavy-emitters will hurt the effectiveness of the program. A carbon tax can be applied evenly across sectors of the U.S. economy. A carbon tax can be designed to be revenue-neutral (paying back evenly-allocated dividends to citizens to cancel-out the natural price inflation that would occur upstream as firms price-in their carbon liability). Carbon tax proponents argue that a tax-based policy would naturally be a “progressive tax.” Affluent citizens would be affected more as they tend to drive more, fly more, and consume more products than less-affluent citizens. However, there is some dispute about this – low-income citizens living in rural areas would suffer a greater impact from higher gasoline prices due to a tax. Proponents of a carbon tax solution also advocate that the simplicity and total-coverage of a carbon tax ensure fast implementation. Design is the cause of the differences in these two approaches. A cap & trade scheme with 100% auctioning that covers 100% of emitting entities would have the same effect as the tax. Although the political forces have swayed toward cap & trade, a carbon tax would be a feasible alternative solution.^{vi}

Economic Impacts on the U.S. Transportation Sector

In 2007, for the first time in over 30 years, the Corporate Average Fuel Economy (CAFE) standards were increased. The CAFE standards aim to abate pollution by attacking the problem upstream during the manufacturing of the vehicles. In 2020, when the changes take effect, the average fuel economy (in miles per gallon) for a car manufacturer's fleet must meet 35 mpg. If the average mpg of a manufacturer's fleet is 0.1 below 35 mpg, a penalty of \$5.50 per 0.1 mpg will be charged to each car manufactured. The CAFE standards are independent of carbon pricing legislation. Several of the cap & trade bills discussed in section VI below allocate a percentage of allowances to the transportation sector, most likely to refiners or petroleum products importers who will pass the costs downstream to consumers.

Economic Impacts on the U.S. Energy Generation Sector

As seen in Figure 5 below, the current U.S. power generation fuel mix is heavily weighted toward coal and impure hydrocarbons (organic compounds consisting primarily of hydrogen, carbon and "impurities" namely sulfur and nitrogen). Coal and hydrocarbon fuels (fossil fuels) are combusted - producing both energy and CO₂e emissions. Other fuel sources (e.g. renewable energy) produce no CO₂e emissions. However, it is important to note that every major fuel source does have upstream carbon exposure, from the CO₂e emitted during the manufacturing of wind turbines, to the diesel fuel burned digging uranium ore out of the ground for nuclear fuel production. Emissions calculations are affected by how far upstream the measurements are taken. Figure 5 focuses on emissions from power generation alone. Currently, the U.S. is heavily dependent on coal as a fuel source with 49% of energy generation coming from coal. Coal is also the dirtiest of the fuel sources accounting for 82.3% of the energy sector's CO₂e emissions.

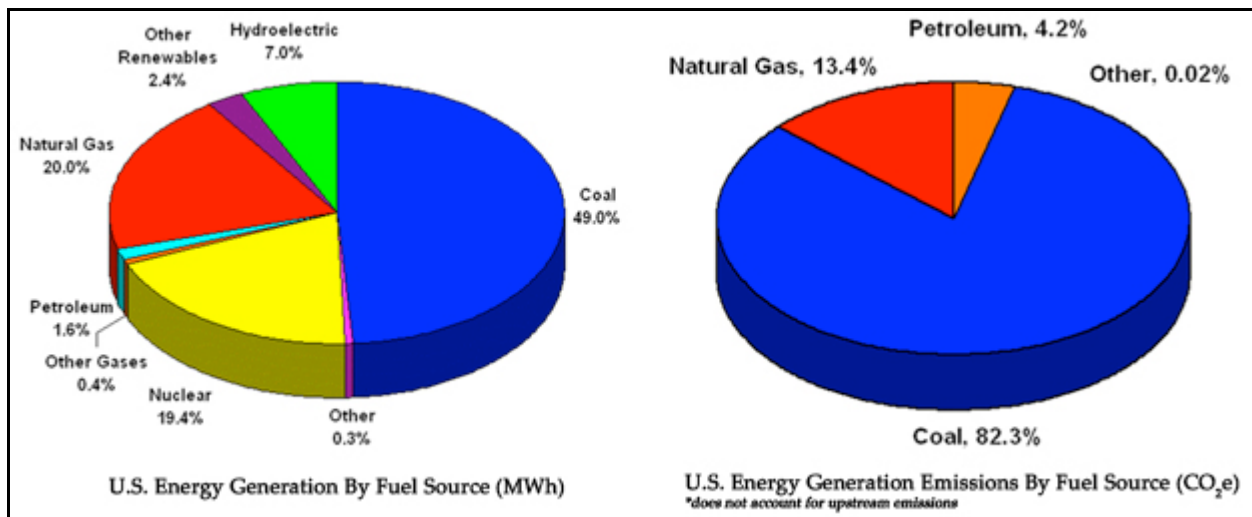


Figure 5: U.S. energy consumption and CO₂e emissions by Fuel Source - EIA, Annual Energy Outlook (2006)

With the exception of the Pacific Northwest, all U.S. geographical regions will have some exposure to carbon pricing through coal-fired power generation facilities. The Northeast, North Central and South Atlantic regions have the highest concentration of coal-fired generation (44%

of the total). Consequently, utilities and independent power producers in these regions will likely have to adjust their electricity rates to consumers to account for the cost of CO₂e abatement.

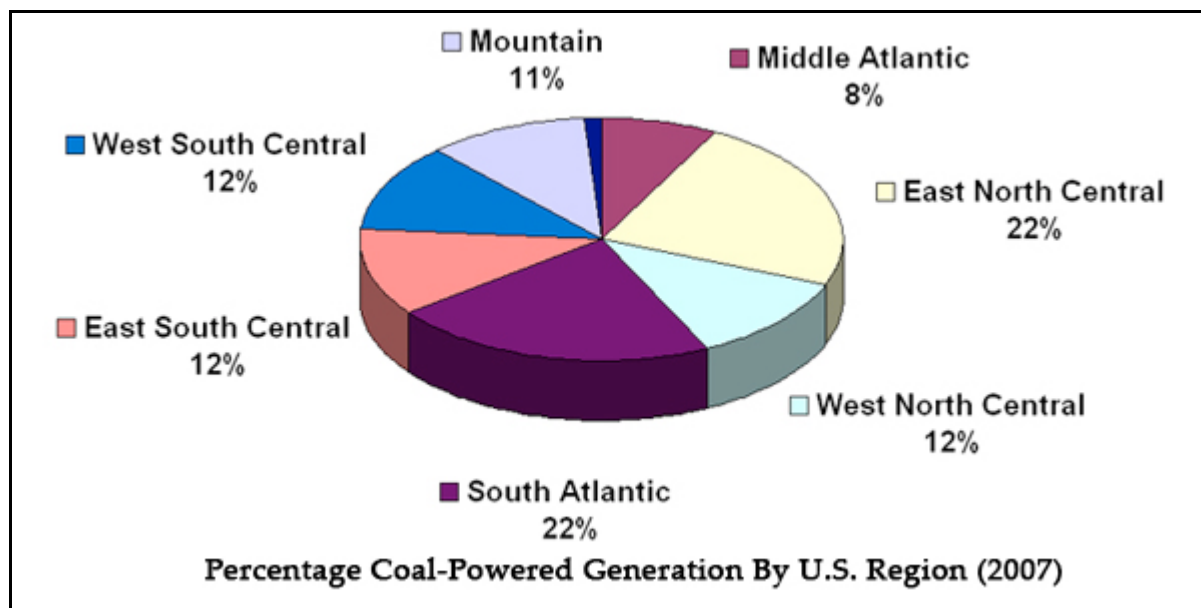


Figure 6: Net Generation of Coal by U.S. region -EIA (2007)⁷

The Coal Industry's Exposure to Carbon Pricing

The U.S. coal industry has significant exposure to carbon pricing. The industry's largest customers (utilities and independent power producers) would be forced to reevaluate their fuel-mix if CO₂e emissions were priced. This would likely result in a migration away from coal as a fuel source, significantly softening market demand (though technologies that would capture and store CO₂ emissions from power plants are being actively researched). If this shift does occur, it is important to understand the consequences this will have on the U.S. economy, and specific coal producing states. According to the National Mine Association (NMA):

- The United States has nearly 268 billion tons of recoverable coal reserves; roughly a 240 year supply at today's usage rates.
- Estimating the average spot price of \$50.00 USD per ton (\$30-70 per ton range in Jan 08') the value before extraction is \$1.34 Trillion USD.
- Worldwide, coal represents an estimated 60 percent of the total fossil fuel reserves.
- In 2005, the coal industry employed 81,891 workers in underground mining, surface mining, processing, independent shops and yards, and office workers.⁸

Several U.S. states have higher indirect exposure to carbon pricing due to their concentrations of coal reserves. Unfortunately, several of the largest coal-producing states are also ranked the lowest in percentage of U.S. GDP, meaning that the greatest economic damage could occur in states that can least afford it (see Figure 7 and Table 1 below).

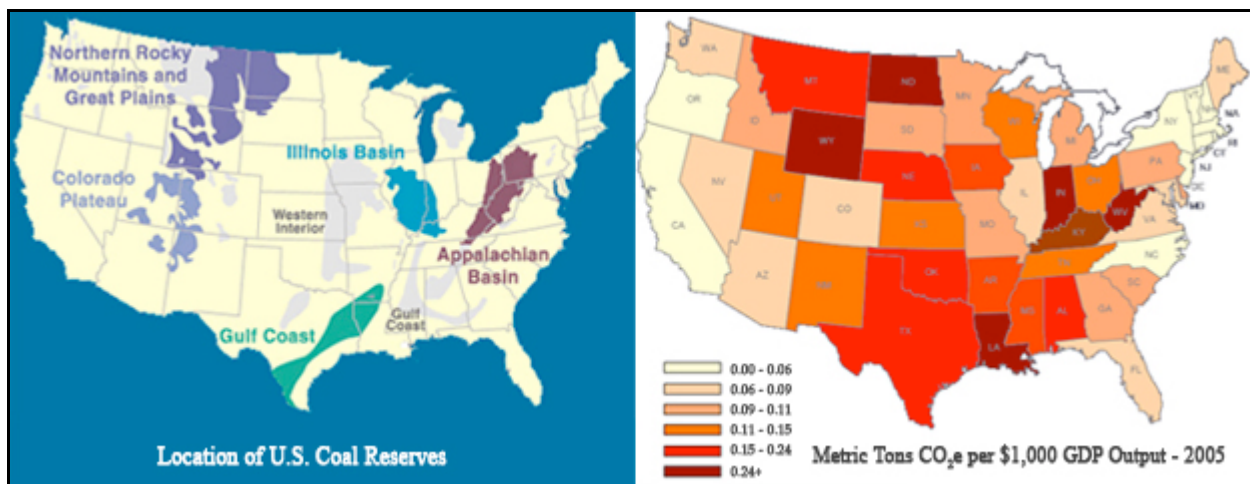


Figure 7: Comparison of coal reserves to tons CO₂e per \$1,000 GDP output- Right: “Coal – A Complex Natural Resource”, USGS (2004), Left: Abt Associates Carbon Emissions Economic Intensity Index

State	2005 Coal Production (Tons)	Gross State Product Rank (1-50)
Wyoming	404,319	#48
West Virginia	153,650	#41
Kentucky	119,734	#28
Pennsylvania	67,494	#6
Texas	45,939	#2

Table 1: BEA Statistics (1997-2006) States by GSP, and Platts.com⁹

V. **Emissions Trading Scheme Design Considerations**

A successful Emissions Trading Scheme (ETS) will provide liquidity to market participants, matching buyers and sellers so that each party may mutually benefit by arriving at the lowest cost-compliance solution. ETS's have several design considerations that are actively debated; from the high-level choice between cap & trade and rate-based schemes to the choice between auctioning and free allocation (grandfathering) of allowances to existing installations.

Grandfathering vs. Auctioning Allowances to Existing Installations

A core question is whether the policy framework should freely distribute allowances, or distribute a percentage of the allowances for free and auction the remainder. There are trade-offs with each approach. Auctioning has been proven to be more successful at reducing distortions that prevent fair distribution of credits, as the bidders shape the auction price. Many critics of the EU ETS claim that poor historical emissions data resulted in an over supply of grandfathered allowances that hurt the environmental effectiveness of the program. On the other hand, there are certain sectors of the economy that have heavy exposure to CO₂e through historical investment decisions (e.g. the U.S. coal industry). In fairness, these firms should be given time to shift their investment strategies away from emissions-heavy assets to allow them to compete against unconstrained competitors. If sound data can be gathered, grandfathering allowances to these firms may be the only way to even the playing field.

Proponents of allowance auctioning believe that there is a balanced weighting between free allowances and auctioned allowances that would not force negatively affected firms to devalue their assets. If transparency to affected assets could be provided, regulators would be able to efficiently distribute allowances thereby reducing the percentage of free allowances that would be needed.

Cap & Trade vs. Rate-based Trading Schemes

A cap & trade scheme sets the total quantity of pollution (e.g. allowable tons of CO₂e) that regulated sectors can emit during a specific period. Firms must secure allowance credits to cover each ton of pollution they emit. If a firm does not hold the necessary quantity of allowances after the initial allocation (whether by grandfathering or auction), it must purchase the additional allowances through an ETS. Firms below the cap are able to monetize the excess allowances by selling them in the market. The emissions cap is then lowered over time via the allocation (through auctioning or grandfathering) of fewer allowances in successive compliance periods, thereby reducing the total allowable pollution emitted.

Figure 8 below illustrates the basic principles of the cap & trade scheme. As demonstrated, a company (Firm A) with higher clean-up costs may find reducing its own emissions expensive relative to purchasing allowance credits in the market from a company (such as Firm B) with lower clean-up costs. Firm B can thus increase its profits by eliminating a higher proportion of its emissions than the standard requires and selling its excess allowances to Firm A. Emissions

by the industry as a whole remain below the cap. This market-driven solution minimizes dead-weight loss often caused by regulation, which leads to the income maximizing level of allowable pollution. Importantly, a cap & trade system balances the benefits of pollution control with economic costs of abatement.

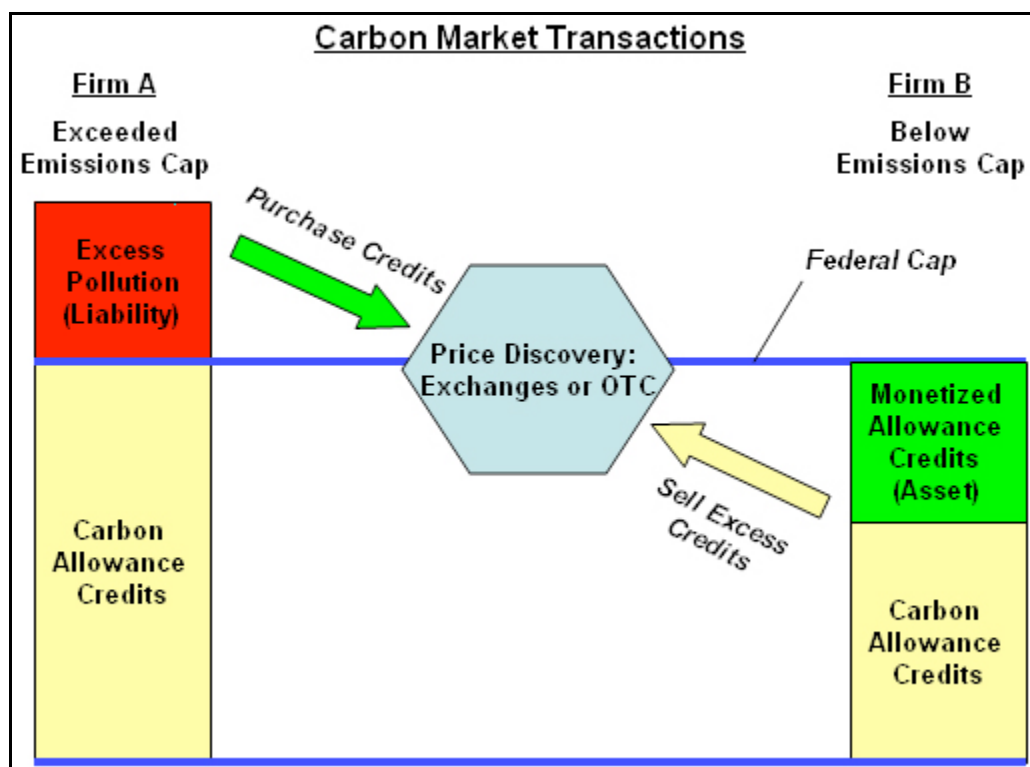


Figure 8: Carbon Market Transaction Example, - Clean Energy Incubator (2008)

A rate-based scheme is analogous to an indexed (or floating) cap, where allowances are generated for meeting a target ratio of emissions to output. For example, if the electricity demand increased by 5% under a mechanism, yet the ratio of emissions to electricity generated remained the same, the total pollution generated would increase, but the abatement ratio would still meet the scheme's requirements. Because increased energy consumption could render this model ineffective, a majority of existing or proposed ETSs are pursuing a cap & trade design.

Policy Lead-time and Certainty

Critical to the success of any Emissions Trading Scheme (ETS) is the certainty and lead-time of the policy change. Once the decision is settled, firms are able to adjust their investment strategies, update their financial models, and depreciate existing assets appropriately over the time horizon stipulated in the policy. To help firms make these adjustments, the ETS must be concrete, and clearly articulate the reduction goals and allowance retirement schedule.

Preventing Outsourcing “Carbon Leakage”

Equally important is ensuring that U.S. firms remain competitive in the U.S. markets through the use of export incentives and import taxes against international firms that are not required to internalize the cost of greenhouse gas emissions. “Carbon Leakage” could occur if emissions-intensive U.S. industries move from compliance markets to non-compliance markets outside the U.S. where they are not taxed on emissions. This would have an adverse effect on U.S. GDP, and policies would need to be established to mitigate this risk. Some economic sectors, geographic regions, and income groups will be disproportionately impacted by a cap & trade program. Careful thought must be given to how to even the playing field, and minimize economic losses.

Providing R&D Investment Incentives

Another important consideration is how to incentivize capital-intensive research and development for cleantech in the U.S. Such investment will ensure that U.S. firms benefit from the economic windfall that will occur when innovative technologies are developed and deployed to meet evolving cleantech demand. This will also ensure that we learn from and do not repeat the experiences relating to how economic value was realized from the compliance requirements of the cap & trade programs for sulfur oxides (SO_x) and nitrogen oxides (NO_x). For example, many utilities found themselves purchasing catalyst products and technical expertise from European engineering conglomerate Siemens AG in order to bring NO_x emissions into compliance. This economic value was exported across the Atlantic rather than remaining in the U.S. economy. To ensure the U.S. is ready to capitalize on the economic benefits, a scheme must incentivize innovation and early adoption to accelerate the deployment of low-emissions technologies created by domestic firms. A strong argument for auctioning some or all of the emissions allowances under a cap & trade scheme is that the resulting revenue can be used to fund R&D. A tax-based scheme also would generate revenue that could be used for this purpose.

Economic Coverage of the ETS

There are different degrees of economic coverage in several of the proposed ETSs. Some of the upstream and downstream sectors that have exposure are the forestry and aviation industries. A federal ETS in the U.S. should include all greenhouse gas emissions. Essential to the success of any ETS is the flexibility to quickly amend the system if environmentally negative or economically negative loopholes are discovered.

Carbon Offsets and Renewable Energy Credits (RECs)

Most cap & trade schemes allow the government to issue additional allowances (in excess of the “cap” level) to firms that can generate offsets. A Carbon Offset is a project that removes CO₂e from the environment that otherwise would have been generated. This can take one of several forms including the creation of new carbon sinks through investment in forestry, changes in agricultural practices, investment in renewable power, or investments in energy efficiency. A common form of offset project in existing schemes is investment in emissions reduction projects in developing countries. By purchasing these offsets, a firm with a high level of emissions can buy time to invest in cleaner technology. Individuals can also purchase offsets to reduce their

carbon footprint. In effect, by purchasing negative amounts of carbon, their net balance could be reduced to zero.

A Renewable Energy Credit (REC) is created when electricity is generated from a renewable energy source according to the terms of a specific renewable energy program. Most RECs are created under the legislative provisions of a state renewable portfolio standard (RPS). A lesser number are associated with voluntary programs such as the L.E.E.D program. In essence, when the renewable energy producer operates, two products are created, electricity and RECs. One megawatt hour of (certified) renewable power generated equals one REC, which represents the extra value of that energy over that of non-renewable power. Once electricity is created there is no way of telling that it came from renewable or non-renewable sources. For example, a wind developer has the flexibility to either sell the two products together as “Renewable Electricity”, or sell the RECs and electricity separately. When a utility customer opts to pay more for a “Green Choice Program” the additional cost finances the purchase of RECs. In fact, the customer may be getting electricity produced from a coal-fired power plant that a utility purchased RECs to convert the electricity to “Green Choice.”

There are two important differences between carbon offsets and RECs. One is that Renewable Energy Credits are by definition related to the generation of renewable energy, whereas carbon offsets come from a wide variety of projects that reduce CO₂e emissions. Several examples include programs to make homes more efficient, certain types of land conversion, or carbon capture and sequestration. Purchasers of carbon offsets are helping to fund projects that are not “business-as-usual” (i.e. funding projects that otherwise would not be economically feasible). Carbon offset projects are often referred to as “additional” meaning that many standard, business-as-usual measures would reduce carbon emissions, but because these actions would be taken anyway, they are not considered offsets. Only projects that are done “in addition” to actions that would have been taken qualify as carbon offset projects.

Carbon Offset Project Validation

Carbon offsets can be tricky to quantify - would planting a forest on un-used land qualify for carbon offset credits? What would the value of the credits be if the forest burns down and releases all of the CO₂ back into the atmosphere? Different voluntary markets have different rules for how offset projects are quantified. There has been a lot of criticism of the offset component of the EU Emissions Trading Scheme – many of these offset projects were not properly verified, and the system was exploited. Specialized auditing firms have been set up to deal with these questions – for example, a company called Greene-E has made its mark in the industry by certifying projects. They certify that RECs are truly from renewable sources, and are only being sold once. They also verify carbon offset programs. It is estimated that Green-E now certifies 50% of RECs in the U.S. market. They have different types of approvals varying with the type of project: Gold Standard, Voluntary Carbon Standard 2007, Clean Development Mechanism, and Green-E Climate Protocol. However, this is a voluntary standard. Many Producers of CO₂ offsets do not get their offsets independently certified and as Nancy Hirshberg, VP of Natural Resources at Stonyfield Farm says, “Many projects are simply not verifiable, it’s definitely a buyer beware market.” Right now in the U.S. all offsets are traded on a voluntary

basis, with the Northeastern states and California moving towards mandated markets. A key concern of U.S. industry is the inclusion of offsets in a federal cap & trade system.

If cap & trade legislation were to pass, it is likely that RECs would continue to exist as a manner of helping finance alternative energy sources, also an important political issue. Carbon offsets may continue but under much stricter rules. Rep. Ed Markey (D-MA) has recently been pushing the Federal Trade Commission to clarify what can and cannot count as carbon offset producing projects, tracking the actual carbon negated, and making sure the credits are not sold more than once. Many U.S. firms are acquiring positions in carbon offsets in anticipation of federal legislation, hoping that they will be given an initial CO₂ assessment at a lower level for holding these credits (frequently referred to as early action credit). For example, Entergy recently purchased a large amount of offset credits from Nike, hoping to “bank them” (hold the position).

Integrating Carbon Offset and Carbon Allowance Markets

Renewable Energy Credits (RECs) are a category of carbon offsets created from the production of renewable energy (wind, solar, geothermal, etc.). RECs are expressed in terms of kilowatt hours (one REC equals 1,000 kWh (1MWh) of renewable electricity produced). But what volume of CO₂e was “offset” from the generation of 1,000 kWh of clean energy? Is the reduction quantifiable? This is a challenging question that requires consideration of a long list of variables. How many pounds of CO₂e would have been emitted by the non-renewable generation asset? Price discovery is challenging enough in the REC market without the added complexity of unit conversion. The E.U.’s ETS program has integrated these two categories through their Clean Development Mechanism (CDM) which allows firms to meet the ETS’s requirements through purchasing CDM offsets (some of which are generated through renewable energy projects.)

The political risk associated with the rules around the verification of various offset categories is high. This harsh lesson was recently demonstrated on Agcert, a U.K.-based methane capture company. The United Nations adjusted their calculation for gas reductions which significantly reduced the amount of methane that firms like Agcert could count in their CDM projects, drastically reducing the value of their credits, and dropping the market value of their public equity.¹⁰

VI. **Carbon Market and Renewable Energy Legislation**

As scientific evidence piles up and concern about the potential effects of global warming on the economy grows, the current 110th Congress has been more active than any of its predecessors in introducing legislation related to energy efficiency and climate change. According to the Pew Foundation, as of mid-July 2007 this Congress had introduced more than 125 bills, resolutions, and amendments specifically addressing global climate change and greenhouse gas (GHG) emissions. The five Acts that have received the most attention are summarized below.

The Lieberman-Warner Act (America's Climate Security Act)

Introduced in the Senate on October 18, 2007; approved by the Senate Environment and Public Works Committee on December 5, 2007; Harry Reid – Senate Majority Leader – has promised to bring it to the Senate floor. The following sections summarize the Act's design.

Coverage

The proposed bill is based on a cap & trade scheme covering specified facilities within the electricity generation, coal and oil based transportation fuels and other industries, responsible for over 80% of U.S. emissions¹¹. The bill includes a domestic offset program for sequestration in agriculture and forests. Up to 15% of a facility's compliance obligation may be met through offsets, and up to an additional 15% through purchases from approved trading systems abroad.

Target Reductions

The proposed bill requires cuts in emissions from 2005 levels from the covered sources¹² of 4% by 2012, 19% by 2020 and 71% by 2050. The NRDC and World Resources Institute estimate that the cuts in total U.S. GHG emissions would be 5-13%; 18-25%; and 62-66% respectively.¹³ The sponsors estimate that the bill would keep the atmospheric concentration of CO₂e below 500ppm, on conservative assumptions about other countries' reductions.

Allocation of Allowances

The proposed bill establishes the Climate Change Credit Corporation to auction and distribute allowances. Designated beneficiaries will either receive allowances directly or funding from the proceeds of auctions. Allowances or auction proceeds for 2012-2050 will go to:

- Free allocation to industry based on past emissions: 12% (to be phased out by 2030)
- Consumers, states and tribes: 31%
- Low carbon technology development and deployment:
 - Sustainable energy and zero- or low carbon energy technologies: 17%
 - Advanced coal and sequestration technologies program: 9%
 - Mass transit; fuel from cellulosic biomass; advanced vehicle technologies: 7%
 - Soil sequestration and methane reduction: 8%
 - Worker training: 3%
 - Global warming impacts, including wildlife and international aid: 13%

The Act also sets up the Carbon Market Efficiency Board to provide relief measures if it determines that the scheme is causing significant harm to the economy. However, unlike some of the previous bills dealing with climate change, it does not include a safety valve to operate if the price of allowances gets too high.

Other Measures

An amendment adopted in committee added a low carbon fuel standard to the bill. The amendment requires a 5% cut in GHG emissions per gallon of gasoline equivalent by 2015 and a 10% cut by 2020. It also stiffens energy efficiency requirements on appliances and buildings and takes measures to establish a legal regime for underground CO₂ sequestration, including setting up a task force to look at consequences of a possible federal assumption of liability. It establishes an interagency group to examine how foreign countries have addressed the GHG issue. After an appropriate delay, countries that have not enacted effective measures to reduce emissions of GHG will be required to produce allowances to cover imports of GHG-intensive products to the U.S.

Comments

Environmental groups in general extend somewhat lukewarm support to the Lieberman-Warner bill. Their view seems to be that it is not enough, but it is the best bill that has a chance of being approved at the present time. They hope to ensure that the eventual bill contains a provision for periodic review by the legislature in the light of expanding knowledge of climate change science.¹⁴

The Lieberman-McCain Act (Climate Stewardship and Innovation Act)

Senators Lieberman and McCain introduced their Climate Stewardship Act in the Senate in September 2003; it was voted down by a margin of 43-55. The bill was reintroduced in 2005, but suffered the same fate. The latest version, introduced on January 12, 2007 was co-sponsored by Senators Hillary Clinton and Barack Obama. It appears to be stalled in committee.

Coverage

The bill proposes a cap & trade scheme to operate from 2012, covering entities that own or control facilities in the electricity generation, industrial or commercial sectors of the U.S. economy that emit more than 10,000 tons of GHGs per year. These facilities are responsible for about 75% of U.S. GHG emissions. Up to 30% of an entity's required allowances may be earned through domestic sequestration activities and by participating in schemes to cut emissions in developing countries.

Target Reductions

Resources for the Future (RFF) estimates that the effect of the Lieberman McCain bill would be to cut total U.S. emissions 39% by in 2030 and 59% by 2050.

Allocation of Allowances

The bill establishes the Climate Change Credit Corporation (CCCC) to administer the scheme. The method of allocation is left largely up to the EPA, but as the bill provides for the CCCC to fund various research programs and subsidies, an auction of at least a proportion of the allowances is clearly intended.

Other Measures

There is provision for funding of research on low carbon technologies, sequestration of GHGs and technologies to aid adaptation. There is also a provision for government investment in technologies that originate in the private sector and the creation of public/private partnerships. Some specific programs are:

1. Research into advanced nuclear reactor technology and the associated fuel cycle issues. Sets up a program to reduce the regulatory costs inherent in the Nuclear Regulatory Commission licensing process.
2. Demonstration project on competitiveness of advanced low carbon vehicle technologies.
3. Sets up an interagency panel to establish standards for carbon sequestration proposals.
4. Provision for energy audits of large commercial entities to encourage conservation.

Comments

Senator McCain believes that nuclear must be a key part of any solution to the problem of climate change. It has been suggested that the only reason he did not co-sponsor Lieberman Warner was that bill's failure to include any specific acknowledgement of this issue.¹⁵

Other Bills

Of the myriad of bills that have been introduced in both houses of Congress and then, in one way or another, stalled, it is worth mentioning the Bingaman-Specter (Low Carbon Economy Act). Introduced July 11, 2007, this bill is widely seen as weak. Its targeted cuts are relatively unambitious and it mandates the government to issue additional allowances if the market price in normal trading rises above a pre-set level – thus nullifying the intent of the cap.

The Energy Independence and Security Act of 2007

The Energy Independence and Security Act of 2007 was signed into law on December 19, 2007. This Act started life as part of the Democrats' action plan for the first 100 business hours of the 110th Congress. The final version focuses on:

1. Automobile fuel economy standards (the CAFE standards): automakers are required to boost fleet average fuel economy to 35mpg by 2020. The limit applies to both cars and light trucks (SUVs), though the application of the regulations to SUVs is still uncertain following the rejection of some aspects of previous regulations by a Federal Appeals Court.
2. Greater usage of biofuels: the amount of biofuels added to automotive and home heating fuels is to increase to 36 billion gallons by 2022, starting from a targeted 8.5 billion gallons in 2008. Of the 2022 total, 21 billion gallons must be derived from sources other than corn ethanol.

3. Higher energy efficiency standards for appliances and lighting, and new initiatives for improving the energy efficiency of existing homes and government buildings. The sale of most incandescent light bulbs will be banned in 2014.
4. Increased support for research into renewable energy, carbon capture and storage (CCS) and smart grid systems, and for training workers in “green jobs.”

Some provisions of the original version of this Act were dropped to ensure its passage through the Senate. Most of these are being resuscitated in the form of:

The Renewable Energy and Energy Conservation Tax Act of 2008

This bill passed the House of Representatives on February 27, 2008 (one of its co-sponsors was Rep. Lloyd Doggett of Texas). Key provisions taken from the original draft of the earlier bill include the extension of existing tax credits for wind, solar and other renewable energy and domestic efficiency improvements and the creation of some new incentives – for example, investment in plug-in hybrid vehicles and cellulosic ethanol. The total cost of the bill is estimated at \$18.5bn. This is to be funded by the repeal of certain tax credits enjoyed by major oil companies, including subsidies on domestic oil and gas production (small independent producers will continue to benefit from these subsidies). The bill now goes to the Senate.

The American Renewable Energy Act

In the meantime, the American Renewable Energy Act was introduced in the Senate on February 14, 2008. It includes most of the provisions of the bill that has now made it through the House, plus a requirement that utility companies must produce at least 25% of their electricity from renewable sources by 2025.

The Candidates’ Positions

Senators McCain, Clinton and Obama are all on record as saying that global warming is happening, that it is largely caused by human activities and that the United States needs to seize the initiative in dealing with it. The two surviving Democratic candidates’ positions have been laid out in detailed plan documents. Senator McCain has not issued such a document, which makes direct comparisons harder.

Senator McCain’s exact position on some issues is vague. However, it is clear that his views on global warming are at odds with the views of many in his party. He believes that the climate is getting warmer and that human activities are the principal cause. He supports a cap & trade system (the Lieberman-McCain Act mentioned above). He supports higher automobile fuel economy standards and increased use of renewables and biofuels. He also supports clean coal and nuclear energy.¹⁶

The detailed plans issued by Senators Clinton and Obama have a great deal in common, though Senator Clinton’s contains more detail and more quantified targets. Both support a cap & trade scheme to cut U.S. emissions of carbon dioxide to 80% below 1990 levels by 2050, and both would auction 100% of emissions allowances. Both support clean coal, which in this context

means the capture and underground sequestration of CO₂ emissions. Both want the fuel economy standards for automobiles (the CAFE standards) raised to 40mpg by 2020. Both would set a target of generating 25% of U.S. electricity from renewables by 2025 (Senator Clinton would make the renewable production tax credit (PTC) permanent and Senator Obama would extend it by five years). Both want 60 billion gallons annually of home-grown biofuels available for use in vehicles by 2030. Both support mass transit (Senator Clinton also mentions inter-city train services and Senator Obama mentions bicycles and walking). Both support coal-to-liquid fuels provided these fuels can be shown to emit 20% less carbon on a lifecycle basis than petroleum based fuels. Both are lukewarm on nuclear. The Democratic candidates' plans contain a number of proposals of direct relevance to small and medium sized businesses.¹⁷

Issue	Clinton's Position	Obama's Position
Green jobs / investment in industry	Create 5MM jobs in clean energy and efficiency over the next decade; assistance to oldest auto plants in retooling.	Job training and transition programs; Federal investment to help manufacturing centers gear up to produce clean technology products
Green buildings	Weatherize 20MM low-income homes; provide energy efficiency home improvement loans to up to 100,000 homeowners each year.	Expand Home Energy Assistance Program; expand weatherization grants; set target for all new buildings to be carbon neutral by 2030 and for improvements in existing buildings.
Small scale wind and solar	Tax breaks for the installation of small scale renewable energy such as rooftop solar; net metering so consumers can sell electricity back to the grid.	Enable consumers who have installed their own generation capacity to sell electricity back to the grid.
Community ownership of biofuels facilities		Incentives for local communities to invest in biofuels refineries.
Venture capital investment in clean technologies		Create a Clean Technologies Deployment Venture Capital Fund – invest \$10B for five years.

VII. Existing and Proposed Carbon Markets

Globally, there are a variety of carbon markets that exist today, or have been passed into law and will become active in the next few years. The European Union's ETS is the largest multi-national market developed to meet Kyoto Protocol abatement targets. It integrates a cap & trade model for allowance credits with a subset of offset credits from Clean Development Mechanism (CDM) projects in developing nations. Over 12,000 installations in the EU must meet emissions levels or purchase additional allowances over-the-counter or via one of Europe's climate exchanges. In the first phase of the EU scheme (2005-2007), EU nations unintentionally over-allocated allowances. The result was that EU allowances unit (EUA) prices collapsed between March and September 2007 resulting in virtually worthless allowance credits. The EU has tried to compensate for this failure by cutting the number of allowances for the second phase (2008-2012), but some EU countries have gone to court to dispute their allowances – there are some obvious lessons here for future U.S. schemes.

Several regional GHG compliance markets are being developed here in the United States in the absence of federal involvement in the Kyoto Protocol (see Figure 9 below). The Regional Greenhouse Gas Initiative (RGGI) aims to reduce CO₂ emissions from power plants in eight northeast states. Additional GHGs may be added in future amendments to the initiative.¹⁸ The Midwestern Greenhouse Gas Reduction Accord (MGGRA) was approved by six Midwestern states in November, 2007 and reduction levels will be agreed upon by November, 2008. MGGRA aims to focus financing efforts on clean-coal and carbon capture and sequestration technologies due to the large reserves of coal in the Illinois basin.¹⁹

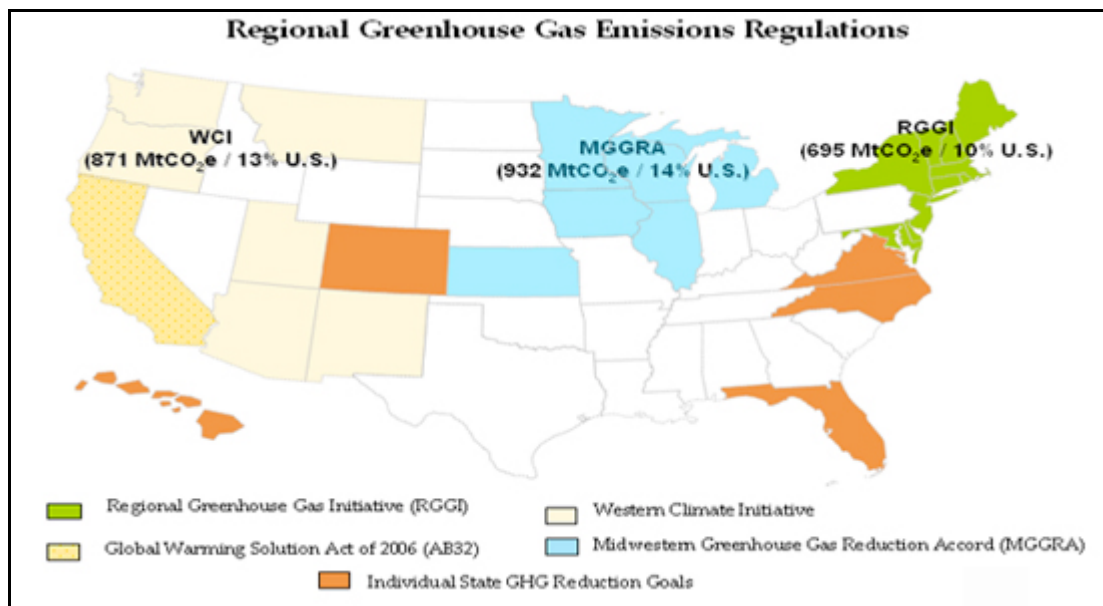


Figure 9: Regional GHG Markets - Element Markets, LLC (2008)

Emissions Trading Exchanges and Registries

The Chicago Climate Exchange was the first, and has been the most active voluntary market for allowances and offsets. Firms voluntarily sign legally binding contracts to meet baseline targets established by CCX. To date, the CCX's baseline covers 226MM tons of CO₂e (roughly 4% of annual U.S. GHG emissions)²⁰ with over 350 participating member firms. The NYMEX, the world's largest physical commodities futures exchange,²¹ is launching the Green Exchange on March 17, 2008. The Green Exchange will offer environmental futures, options, and swap contracts. Additionally, several European exchanges trade allowances and offsets. The world's largest climate exchange, in Amsterdam, is owned by the CCX.

Renewable Energy Credit Markets

Twenty-five U.S. states have enacted Renewable Portfolio Standards requiring a percentage of electricity generation to be from renewable energy. The State of Texas has its own REC system that was initiated in 2000. The Electric Reliability Council of Texas (ERCOT) and the PUCT oversee it. Each competitive retail electric provider is required to purchase and retire a certain amount of RECs a year. This is meant to spur development of renewable energy projects, which generate RECs. Figure 10 below illustrates that this young market is highly volatile. Prices spiked at the creation of the program, and fell off in 2005 when regulatory changes reduced the number of RECs required to meet the RPS.

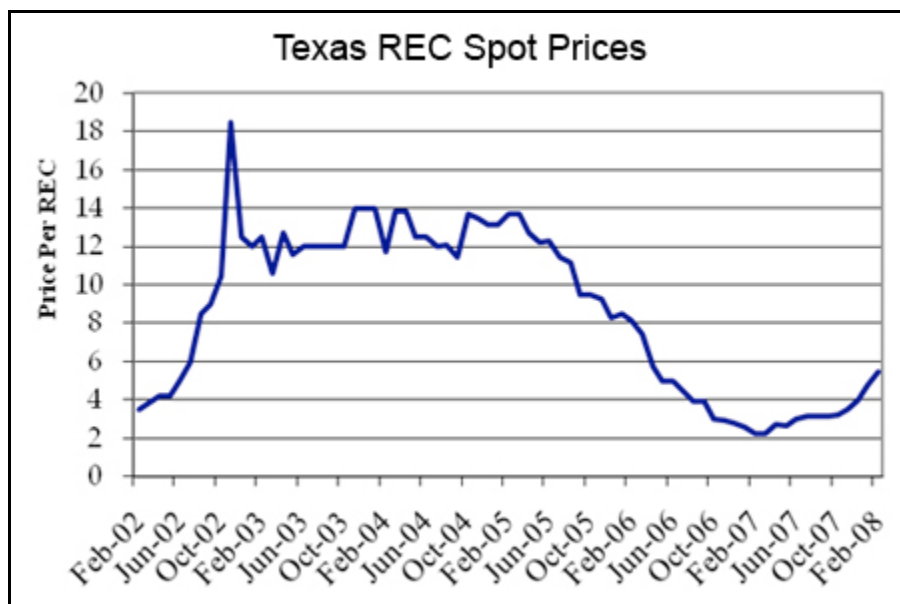


Figure 10: Texas REC Pricing 2002-2008 - Element Markets, LLC

VIII. Austin and Texas Opportunities

Entrepreneurial Opportunities in Texas

A federal cap & trade mechanism will have *significant* consequences for the State of Texas.

If Texas was a country, it would be the eighth-largest emitter of greenhouse gases in the world, contributing roughly 640 million tons of CO₂e in 2005.²² In the last century, many heavy-emitting industries, including petrochemical, fuel processing, and manufacturing developed around the gulf coast of Texas due to its proximity to shipping lanes, access to crude products, and its abundant energy in the form of natural gas. These industries consume large amounts of energy and electricity, largely generated from fossil-fuels. Gradual carbon price increases will encourage these industries to invest into new production technologies, and energy-efficiency. It will also encourage them to diversify their product and energy portfolios, and participate in the REC and offset markets. Most of the large industrial companies in Texas that have large energy portfolios already participate in these activities and price hedging. As carbon prices increase over time, they will expand their risk management portfolios to account for multiple carbon pricing scenarios.

Like many historic structural changes in the energy market, Texas has long evolved and adapted to becoming a leader in providing services to these opportunities. A market based on increasing carbon prices will stimulate the growth of new energy financial services and technology services while the fundamental underlying businesses remain healthy and/or diversify their business models.

As investment, both private and corporate, moves into development technology solutions, Texas stands to gain. Entire new classes of clean technology products and services will emerge. As these industries are built in or migrate to Texas, a new class of clean entrepreneur and green collar jobs will be formed. Secondly, deploying the technologies developed and manufactured in Texas to wind and solar projects will create a set of opportunities for “cleantech wildcatters.” This will develop cleantech project finance, development services, maintenance services, operational services, and land development/management services. Rural Texas has a lot to gain by using its wind, sun, geothermal, and biomass potential to generate additional revenue streams from new clean technology projects.

For consumers in Texas, carbon pricing (if well designed) could be a zero-sum game or provide net benefits that reinforce the state’s energy de-regulation scheme. As more efforts are taken to provide energy efficiency services as well as renewable energy choices, consumers stand to consume less energy or have more control in having fixed renewable energy rates while carbon-based energy sources continue to increase in price. For example, if a consumer signs onto a fixed price contract with a renewable electricity provider and the price of natural gas doubles or triples, then the consumer will likely pay less for his or her electricity and not be subject to market fluctuations (note: renewable electricity does not require “fuel” other than biomass

energy generation). Further, if energy efficiency and net metering policies are constructed to support consumer choice in conjunction with the carbon strategy of the state, then consumers who install solar or other forms of renewable energy would stand to profit by selling this energy back to the grid at peak price times of the day.

Businesses and consumers also stand to benefit from smart grid roll-outs allowing them to not only generate their own energy, but also by “downloading” inexpensive overnight wind energy, storing it in a battery or thermal management system, and re-deploying this energy during peak times. In addition to buying electricity at a low price and selling it at a high price, consumers and businesses who install energy storage systems could be compensated by a utility or ERCOT as an ancillary service that stabilizes the grid.

Wind Power in Texas

Wind power in Texas first took off after Texas passed its Renewable Portfolio Standard (RPS) in 1999. This legislation mandated that retail electricity providers include 2000 MW of their electricity from renewable sources by 2009, or purchase an equal amount of RECs.²³ Due to rapid growth of wind capacity beyond the RPS mandates this number has since been increased several times. Since 1999, Texas has been the national leader in wind generation, and is predicted to be the top producer of wind energy for the foreseeable future.

The growth of this industry can be attributed to several key factors: A single electrical grid, a friendly regulatory environment, and a legacy of energy development. A legacy of WWII, Texas has its own electricity grid, run by the Electricity Reliability Council of Texas (ERCOT) and the Public Utilities Commission of Texas (PUCT). The regulatory environment has helped to accelerate growth in several ways. Developers are not forced to conduct an environmental impact statement before a project is signed-off, and the state’s PUCT recently promised to build at least 10,000 additional MW of transmission lines to areas with high wind potential. Fortunately, citizens of the state are used to the concept that their land can yield them additional revenue through energy production (our “wildcatting nature”), and are also used to the concept of a large machine on their land extracting it. As Jerry Patterson, Commissioner of the Texas Land Office said in a recent interview, “Texas has been looking at oil and gas rigs for 100 years, and frankly, wind turbines look a little nicer.”²⁴

Wind and other forms of renewable energy also offer the possibility of funding the state’s educational systems. The University of Texas currently gets a majority of its funding from royalties collected on oil and gas wells in Texas²⁵. With the decline of these fields, a new source of income will be needed to finance Texas’s academic institutions. Wind power could step in and generate these sorts of royalties. As the quotation below shows, this financing method has already been successful in the state:

“From only one wind farm located on state land in West Texas (Texas Wind Power Project), the Permanent School Fund has earned more than \$750,000 since installation in 1995. The project is expected to earn more than \$3 million for state schools and create \$300 million in increased economic activity over the 25-year lease period.”²⁶

Solar Opportunities

Texas is currently not a national leader in solar energy, even though it is well positioned to be one. Some of the same conditions that helped propel the wind industry to such prominence in Texas could also help develop solar:

1. Due to Texas' size and southern location, it has the best solar insolation (solar potential) in the United States. West Texas, where many wind farms and transmission lines have emerged, has excellent weather conditions for capturing the sun's energy.
2. Texas is a leader in semiconductor manufacturing, equipment (i.e. Applied Materials), and materials (i.e. MEMC) applicable to solar production.
3. Peak solar generation is highly correlated with peak energy demand, and could be used supplant costly natural gas fired turbines lowering costs to consumers.
4. Solar systems are silent, and can be installed modularly; meaning that they can avoid many of the citing issues that plague coal fired power plants.²⁷
5. Solar installations can be deployed throughout the state to urban and rural areas where they can not only produce peak energy, but also provide grid stabilization during peak loads throughout the state.

Solar Under Wind

The Competitive Renewable Energy Zones (CREZs) process being administered by the PUCT is expected to result in the development of transmission capacity as far west as El Paso. Though this is primarily intended for wind, this could also be a very productive area for solar, and having the transmission capacity leading back to the population centers could help spur development.

Monetizing Abandoned Oil Wells through Carbon Storage or Geothermal Energy

Abandoned oil and gas wells, once considered a liability, may end up as valuable assets for the state of Texas.²⁸ Many of these abandoned wells are suitable for underground CO₂ storage (known as carbon sequestration) and other wells are deep enough to interest geothermal energy developers. A sliver through the central region of Texas is suitable for direct-use geothermal, and the rest of the state is suitable for geoexchange (or heat-pump) geothermal development.²⁹ Geothermal developers benefit from the detailed subsurface analysis that already exists from 100 years of oil and gas exploration, allowing them to cherry-pick the best locations for geothermal facilities.

Livestock Methane Capture Projects

The cattle industry in Texas may be able to monetize the manure from their livestock. Methane, 21 times more potent a greenhouse gas than carbon dioxide, is released into the atmosphere from livestock manure. It accounts for 6.6% of total greenhouse gas emissions in the United States. Offset projects have sprung up all over the Midwest to generate credits by capturing this methane. American Electric Power (AEP), one of the nation's largest utility companies, recently agreed to purchase 4.6 million carbon offset credits from Environmental Credit Corp. (ECC). ECC has started an 11-state offset project to capture methane that includes Texas. AEP's CEO

Michael Morris estimates that a farm with 2,000 head of livestock could generate \$105,000 or more in new revenue over a 10 year period through this program.³⁰

Transitioning Coal Generation

Texas consumed 103,763,000 short tons of coal in 2006, of which 99,661,000 tons was used for electricity generation³¹. About half of this coal was produced in Texas and the rest was shipped in from Wyoming. The “Texas Coal Wars”³² were recently the center of national attention over a proposal by TXU to build 19 additional coal-fired power plants with little pollution control technology (the number was later cut to 3). With SO_x and NO_x pricing from the Clean Air Act already in place, and carbon pricing around the corner, utilities that own coal-fired power plants will have three options to evaluate their financial decisions: install “scrubbers” or other emissions-reduction technology, purchase additional allowance credits, or switch to cleaner fuels. This transition will further increase the opportunities for renewable energy developers. With the market’s increasing awareness of the potential liabilities of electricity generated from traditional pulverized coal plants, many U.S.-based coal utility projects have been scrapped.

Economic Consequences of “Non-attainment” Status

Several major metropolitan areas of Texas are currently in non-attainment status under the federal Clean Air Act (Figure 11 below).

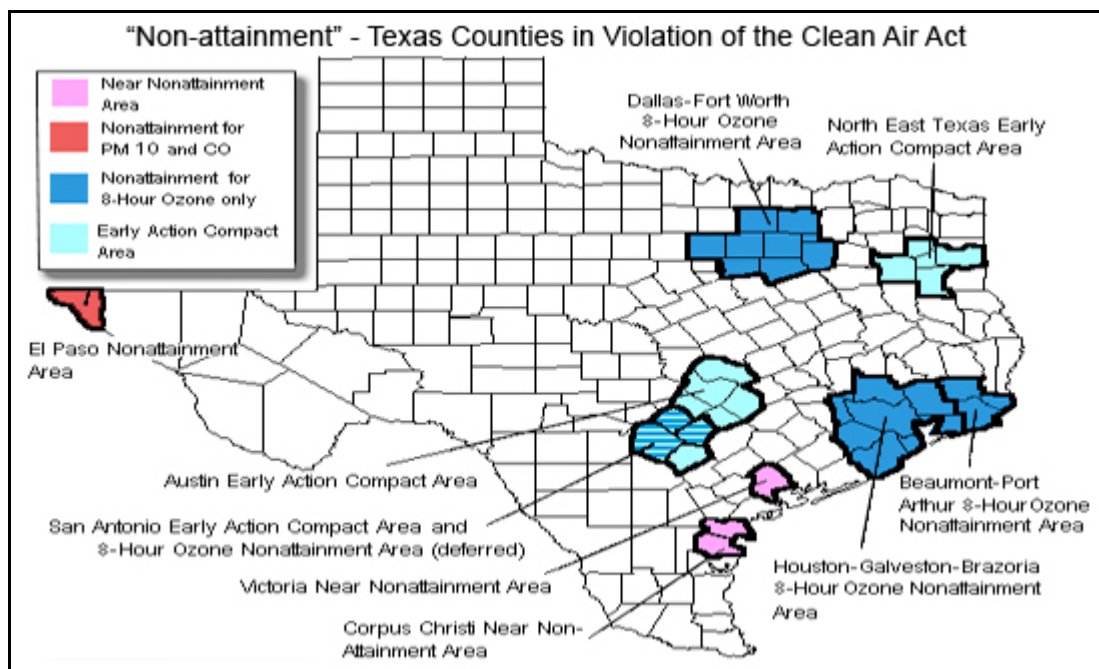


Figure 11: Map of Texas Nonattainment Areas - TCEQ (2007)³³

The areas in violation are:

1. Carbon monoxide and particulate matter in El Paso
2. Eight-hour ground-level ozone in Houston-Galveston-Brazoria, Dallas-Fort Worth, San Antonio, and Beaumont-Port Arthur.

This non-attainment status carries with it several negative economic consequences. A designated nonattainment area must meet strict transportation conformity regulations to receive federal highway funding. Any industry that produces air pollution that wishes to develop facilities in a non-attainment area must meet a “new source review.” To avoid this, many companies choose to locate elsewhere. It also has an intangible negative effect on population growth as the stigma deters families and businesses from moving into the area. For these areas of Texas, removing the non-attainment designation by reducing air pollution would allow their economies to grow faster.

Opportunities for Austin

Austin is already a leader in the cleantech space, with the highest climate change targets of any major metropolitan area, the first Clean Energy Incubator, and some of the largest renewable energy companies in the country. With its leadership, technology entrepreneurship, political center, and its “buying power”, Austin is well-positioned to benefit from the economic growth that will come as a result of carbon pricing.

Austin Energy, one of the largest community-owned public utilities, is part of the reason Austin is leading the nation in renewable energy and energy efficiency programs. Their accomplishments include: the top performing renewable energy program in the nation, the nation’s first and largest green building program, and one of the nation’s most comprehensive residential and commercial energy efficiency programs. The next opportunity will be in deploying the largest smart-grid roll-out in the nation, providing the net metering technology that Austinites are clamoring for. These leading programs will allow Austin to become the nation’s test bed for energy efficiency and clean technologies.

Austin is likely to serve as the “third coast” for clean technology development outside of the Silicon Valley and Boston 128-corridor. New start-ups are forming out of The University of Texas and other innovation centers in Texas and using Austin as their headquarters. Austin is deep in talent from its semiconductor, computer hardware, and software/Internet industries, adding energy storage as an extension of these. Austin stands to benefit from building and recruiting leading clean technology companies who find it a favorable place to execute clean technology business. This innovation center is combined with Houston’s deep experience in project finance, project development, and industrial build-outs. Furthermore, the state’s experience in land development and “wildcatting” will attribute to the entrepreneurial opportunities as carbon prices increase.

IX. Carbon Abatement Technologies and CCS

Abatement Technologies

Although the source of emissions is the focus of most carbon market legislation, the end-user side of the issue cannot be ignored. Energy efficiency and conservation is instrumental to the reduction of greenhouse gases. There is a wide spectrum of carbon reduction (abatement) categories, from the creation of energy-efficient homes, to the capture and sequestration of emissions in energy production. As Figure 12 shows below, there are many carbon reduction categories that could potentially provide positive economic impact if successfully deployed. Unfortunately, the cheapest and easiest-to-implement sources of abatement are challenging for policymakers to work with. It is much easier for policymakers to target a few hundred coal power plants than the general populous, but the “low-hanging fruit” reduction technologies such as insulation and lighting systems in the green-building category should not be overlooked by policymakers as these technologies could provide quick-wins for carbon abatement goals.³⁴

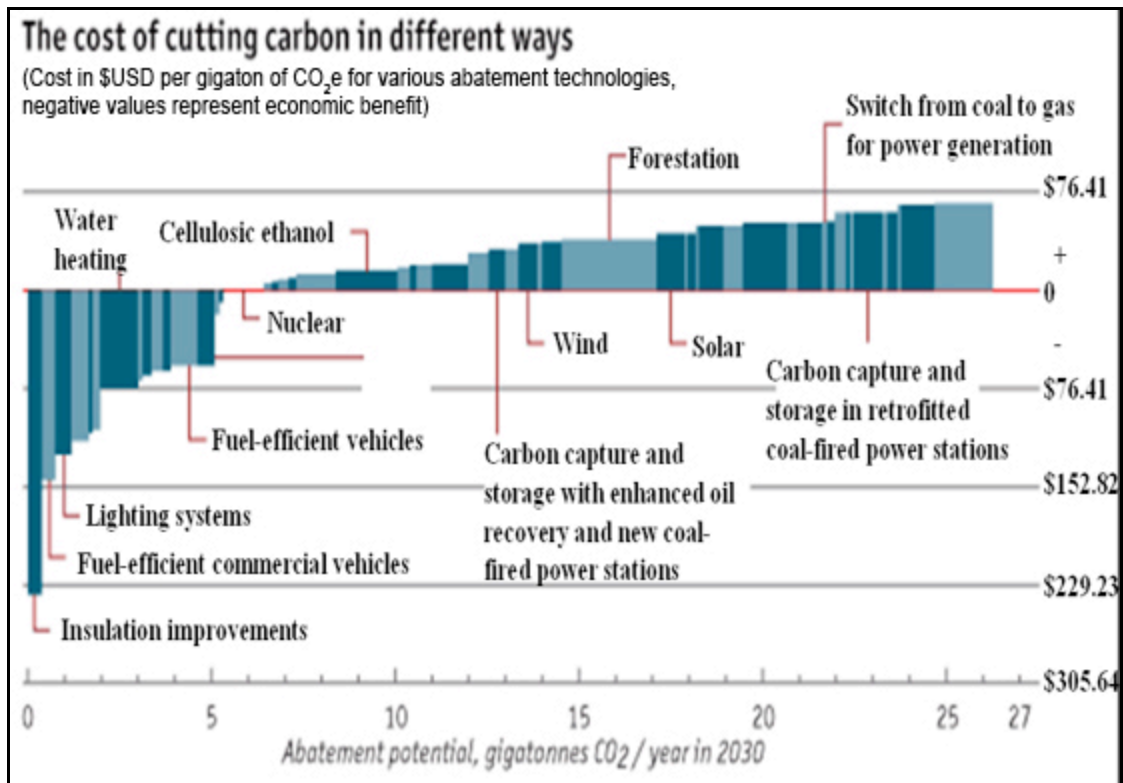


Figure 12: Economic Cost/Benefit of Carbon Reduction Activities - Vattenfall, (2007)³⁵

Carbon Capture

What is Carbon Capture and Storage?

Carbon dioxide (CO₂) capture and storage (CCS) involves capturing CO₂ arising from the combustion of fossil fuels, as in power generation, or from the preparation of fossil fuels, as in natural-gas processing (see Figure 13). CCS involves the use of technology, first to collect and concentrate the CO₂ produced in industrial and energy-related sources, transport it to a suitable storage location, and then store it away from the atmosphere for a long period of time.³⁶

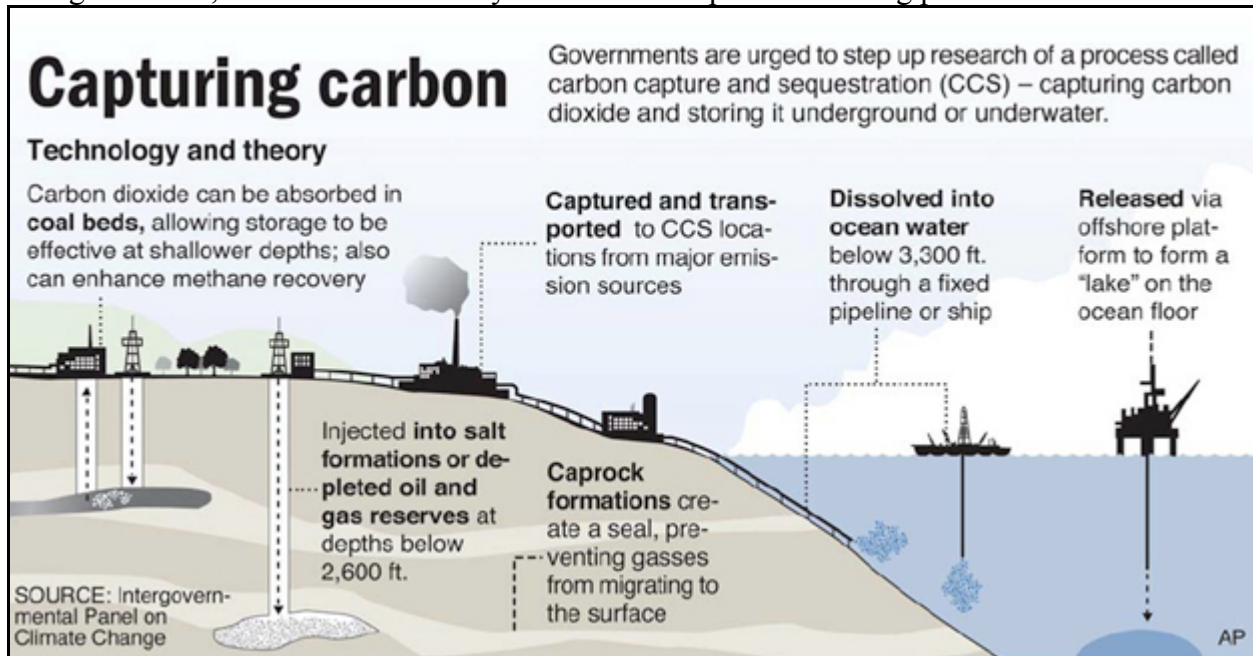


Figure 13: The process of capturing Carbon, Capture, and Storage (CCS) of several steps and technologies -IPCC (2007)

There are three main approaches to CO₂ capture:³⁶

- Post-combustion systems: separate CO₂ from the flue gases produced by combustion of a primary fuel in air.
- Oxy-fuel combustion: uses oxygen instead of air for combustion, producing a flue gas that is mainly H₂O and CO₂ and which is readily captured.
- Pre-combustion systems that process the primary fuel in a reactor to produce separate systems of CO₂ for storage and H₂ which is used as a fuel

Potential storage methods are:³⁶

- Geological storage (oil and gas fields, coal beds, and deep saline formations)
- Ocean storage (direct release into the ocean water column or onto the deep seafloor)
- Industrial fixation of CO₂ into organic carbonates

The net reduction of emissions to the atmosphere through CCS depends on:³⁶

- The fraction of CO₂ captured

- The increased CO₂ production from loss in overall efficiency of power plants or industrial processes due to the additional energy required for capture, transport and storage
- Leakage from transport and the fraction of CO₂ retained in storage over the long run

What is the Regulatory Environment for Carbon Capture?

There are existing regulations in place for over-pressure protection, leak detection, design factors, since CO₂ could leak to the atmosphere during transport, although leakage losses from pipelines are very small. In addition, some regulations for operations in the subsurface do exist, but few countries have specifically developed legal or regulatory frameworks for CO₂ storage.³⁶

What to do with Captured Carbon Dioxide?

The purpose of CO₂ capture is to produce a concentrated stream that can be readily transported to a CO₂ storage site. At present, CO₂ is routinely separated at some large industrial plants, such as natural gas processing and ammonia production facilities; however, there have been no applications at large-scale power plants of several hundred megawatts, the major source of current and projected CO₂ emissions.³⁶

Energy Facilities that can participate in Carbon Capture

The main application of CO₂ capture is likely to be at large point sources:

- Fossil fuel power plants
- Fuel processing plants
- Industrial plants for the manufacture of steel, cement, and bulk chemicals

Capturing CO₂ directly from small and mobile sources in the transportation, residential, and building sectors is expected to be more difficult and expensive than from large point sources.

Transporting from Capture to Sequestration

Transport is the stage of carbon capture and storage that links sources and storage sites. CO₂ is transported in three states: gas, liquid, and solid. Commercial scale transport uses tanks, pipelines, and ships for gaseous and liquid carbon dioxide. Additionally, transport is implemented with land pipelines and ocean pipelines.

Carbon Sequestration

What is Carbon Sequestration?

Carbon sequestration is the placement of CO₂ into a repository in such a way that it will remain permanently sequestered.³⁷ Carbon sequestration refers to the provision of long-term storage of carbon in the terrestrial biosphere, underground, or the oceans so that the buildup of CO₂ concentration in the atmosphere will reduce or slow (see Figure 14). Efforts are focused on two categories of storage, geologic formations and terrestrial ecosystems, and in some cases, this is accomplished by maintaining or enhancing natural processes.

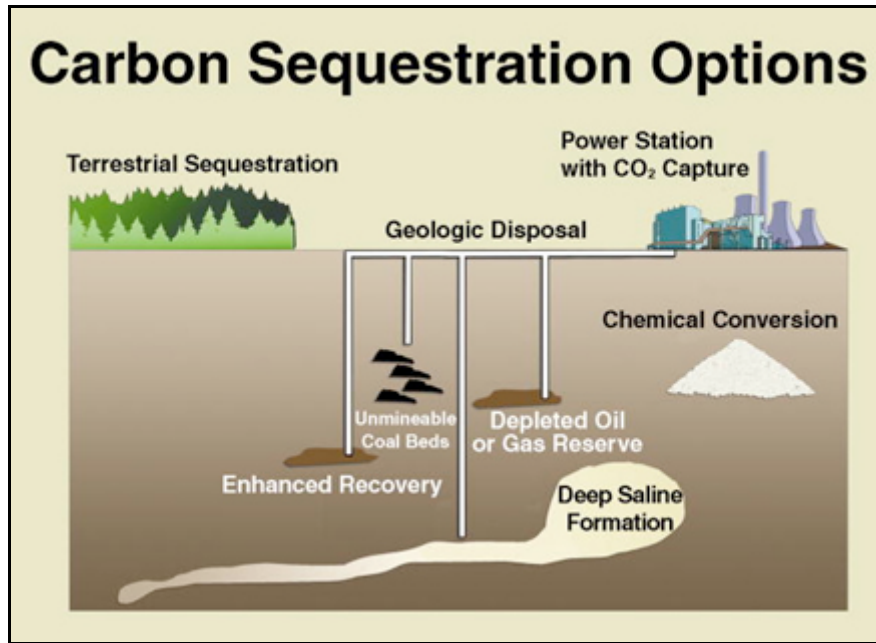


Figure 14: Storage of carbon dioxide -. U.S. DOE Office of Management and Budget

What is Geological Sequestration?

Geological sequestration of CO₂ is defined as injecting CO₂ into deep geologic formations of greater than 1 km for the purpose of avoiding atmospheric emission of CO₂. Potential sequestration sites include:

- Depleted oil and gas reservoirs
- Saline formations and aquifers
- Unmineable coal seams
- Oil- and gas-rich organic shales
- Basalts

The idea of storing CO₂ in geological formations immediately raises questions about storage permanence, the environmental risks involved, necessary monitoring, and the possibility of leaks. There are two types of risk associated with leakages of CO₂:

- Local, site specific, affecting health, safety, and the environment
- Global, resulting from a return of stored CO₂ to the atmosphere

In order to better understand the behavior of CO₂ when stored in geologic formations, the U.S. DoE is conducting research studies to determine the extent to which the CO₂ moves within the geologic formation and what physical and chemical changes occur to the formation when it is injected. The DoE's Office of Science has focused its carbon sequestration efforts on:³⁸

- Sequestering carbon in underground geologic repositories, which involves understanding the geophysics and geochemistry of potential reservoirs

- Enhancing the natural terrestrial cycle through the identification of ways to enhance CO₂ removal from the atmosphere by vegetation or storage in biomass and soils
- Carbon sequestration in the oceans by enhancing the net oceanic uptake from the atmosphere by fertilization of phytoplankton with nutrients
- Sequencing genomes of micro-organisms that produce fuels such as methane and hydrogen.

What is a Geologic “Seal”?

In the context of geologic sequestration of CO₂ in deep formations, the term “seal,” or “caprock,” is used as a general term for one or more layers of rocks that separate the CO₂ injection reservoir from surrounding strata, especially the freshwater zones nearer the ground surface. These relatively impervious layers overlie the injection reservoirs and act to prevent movement of CO₂ and other fluids beyond the injection zones or immediate buffer zones.³⁷

What is Terrestrial Sequestration?

Terrestrial carbon sequestration is the net removal of CO₂ from the atmosphere by plants and microorganisms in the soil and the prevention of CO₂ net emissions from terrestrial ecosystems into the atmosphere. There is significant opportunity to use terrestrial sequestration both to reduce CO₂ emissions and to secure additional benefits, such as habitat and water quality improvements that often result from such projects.³⁷

X. Conclusions

The inclusion of greenhouse gas emissions prices in the financial forecasting models that govern business decisions has already had a profound affect. As the country awaits federal cap & trade legislation, regional and voluntary carbon markets will continue to grow rapidly, filling the gap. They will be championed by state and local government officials, and proactive firms looking to reduce their exposure by swimming with the current, instead of against. The coal industry, and coal-invested utilities will need to innovate quickly to meet the emissions regulations of the future, or they will lose market share to cleaner alternatives. The same is true for auto manufacturers. Entrepreneurs will have an overabundance of problems to solve as emissions-heavy industries invest in cleantech. An ensuing cleantech boom should emerge, benefiting the states and regions that are early adopters of new carbon pricing policies. In the end, carbon pricing will help to bring equilibrium among different forms of energy as we transition to a more renewable and intelligent-energy future.

XI. About the Authors

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Tabrez Ebrahim

Tabrez is currently an Associate at the Clean Energy Incubator and a PhD candidate in the Cockrell School of Engineering at the University of Texas at Austin, where his research focuses on materials, transport phenomena, and systems optimization of direct methanol fuel cells. Previously, he was with Eastman Kodak Company's Research Labs and Growth Initiatives Division, and prior to Eastman, a startup imaging technology company. Tabrez graduated with a B.S. in Mechanical Engineering from the University of Texas at Austin, a Masters in Mechanical Engineering from Stanford University, and a Certificate in Entrepreneurship from Stanford University's Graduate School of Business.

Ian Partridge

Ian is a PhD candidate at the LBJ School of Public Affairs at the University of Texas at Austin, and a Research Associate at UT's Centre for International Energy and Environmental Policy. His research focuses on policy implications of climate change. Prior to coming to UT, Ian worked for twenty years in the international oil industry and related areas, and for several years in investment banking. He has an MBA from the Massachusetts Institute of Technology and a B.S. in Engineering from Cambridge University, England.

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Edward is currently an Associate with the Clean Energy Incubator and pursuing a M.A. in Energy and Earth Resources at the Jackson School of Geosciences at The University of Texas at Austin. Previously he was an associate at Triumph Securities, an investment bank focused on fundraising for the energy sector. Edward has also worked for Fox News, Voice of America, and the Federal Aviation Administration. Edward holds a B.A. in Political Communication from the George Washington University.

XII. Suggested Reading

- “Energy in Flux: The 21st Century’s Greatest Challenge,” Joseph A. Stanislaw (2007)
- Intergovernmental Panel on Climate Change - Synthesis Report (2007)
http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf
- “Voluntary Carbon Markets: An International Business Guide to What They Are and How They Work,” Ricardo Bayon, Amanda Hawn, and Katherine Hamilton (2007)
- “Twilight in the Desert – The Coming Saudi Oil Shock and the World Economy,” Matthew R. Simmons (2005)

XIII. References

Endnotes – Works Cited:

- ⁱ Energy in Flux: The 21st Century's Greatest Challenge, Joseph A. Stanislaw 2007
- ⁱⁱ IPCC AR4 – Topic 1 and 2 - http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_topic2.pdf
- ⁱⁱⁱ IPCC Synthesis Report http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf
- ^{iv} EIA Sectoral Impacts of Carbon Pricing <http://www.eia.doe.gov/oiaf/kyoto/economic.htm>
- ^v EIA <http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html>
- ^{vi} Carbon Tax Center <http://www.carbontax.org/>
- ⁷ EIA Net Generation by Coal by State http://www.eia.doe.gov/cneaf/electricity/epm/table1_7_a.html
- ⁸ National Mining Association, Fast Facts: http://www.nma.org/statistics/pub_fast_facts.asp
- ⁹ State Coal Production <http://www.platts.com/Coal/Resources/News%20Features/cleancoal/table.xml>
- ¹⁰ Dow Jones Clean Technology Investor, “CO2 Credit Co Agcert Delists, Files For Examinership” - Friday, February 22, 2008
- ¹¹ Information on the percentage of US emissions covered by a bill tend not to be available in any official form, while unofficial sources of this information do not always tell the same story. Figures given in this paper are from RFF (Resources For the Future) or the EIA.
- ¹² Information on the extent of the cuts mandated by each bill is easy to find but not necessarily easy to understand. Figures available may refer to cuts from 1990 levels of emissions, from a forecast no-cuts scenario for the target year or from some other year – typically different years for each bill; they may refer to cuts in CO2 or in all GHG measured as CO2 equivalent; they may refer to cuts in the sectors covered by the bill concerned or estimated cuts in US emissions as a whole. Where information is available from more than one source, the figures are often not consistent. A future version of this paper will provide standardized data.
- ¹³ See http://www.nrdc.org/legislation/factsheets/leg_07121101A.pdf
- ¹⁴ See <http://blog.thehill.com/2007/10/29/global-warming-bill-must-be-the-face-of-change-sen-bernie-sanders/> for a statement by Senator Sanders (I-VT). Statements from such organizations as Friends of the Earth are written from a more overtly radical perspective.
- ¹⁵ A short summary of criticism of McCain's position is in the “Environmental Capital” section of the Wall Street Journal of February 11 2008.
- ¹⁶ Senator McCain's speech of April 23 2007 provides the best summary of his environmental views. It is on his campaign website www.johnmccain.com
- ¹⁷ This section is based closely on the detailed plans issued by the candidates and available on their campaign websites.
- ¹⁸ Regional Greenhouse Gas Initiative (RGGI) <http://www.rggi.org/>
- ¹⁹ Midwestern Greenhouse Gas Reduction Accord <http://www.midwesterngovernors.org/resolutions/GHGAccord.pdf>
- ²⁰ Chicago Climate Exchange <http://www.chicagoclimateexchange.com/>
- ²¹ NYMEX <http://www.nymex.com/intro.aspx>
- ²² “The CO2 State” Newsweek, Feb. 2008 <http://www.newsweek.com/id/116784>
- ²³ See http://www.vera.com/downloads/p_texas_model_wiser.pdf
- ²⁴ See <http://www.nytimes.com/2008/02/23/business/23wind.html?scp=1&sq=wind&st=nyt>
- ²⁵ University of Texas Oil Connections <http://www.utwatch.org/utimco/oilfields.html>
- ²⁶ SECO “Texas Wind Constraint” http://www.seco.cpa.state.tx.us/re_wind.htm
- ²⁷ Texas business review, April 2007. <http://www.ic2.utexas.edu/bbr/texas-business-review.html>
- ²⁸ Carbon Storage Comes to Disused Texas Oil Fields <http://www.planetark.com/dailynewsstory.cfm/newsid/28318/story.htm>
- ²⁹ Texas Geothermal Resources http://www.seco.cpa.state.tx.us/re_geothermal.htm
- ³⁰ Power Company to Purchase Carbon Credits from Farms <http://www.farmanddairy.com/1editorialbody.lasso?-token.folder=2007-06-21&-token.story=64992.112114&-token.subpub=>

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- ³¹ Texas Coal Consumption <http://www.eia.doe.gov/cneaf/coal/page/acr/table26.html>
- ³² Edmonton Journal <http://www.canada.com/edmontonjournal/news/business/story.html?id=9b5f7987-2e57-4dbf-bca4-2e9ac85006ed>
- ³³ Texas Nonattainment Areas <http://www.tceq.state.tx.us/implementation/air/sip/siptexas.html>
- ³⁴ Irrational Incandescence, The Economist http://www.economist.com/surveys/displaystory.cfm?story_id=9217972
- ³⁵ Economic Costs/Benefits of Various Abatement Technologies <http://www.vattenfall.com/>
- ³⁶ Metz, Bert, IPCC Special Report on Carbon Dioxide Capture and Storage, Cambridge University Press, 2005
- ³⁷ U.S. DOE, National Energy Technology Laboratory, <http://www.netl.doe.gov>
- ³⁸ U.S. DOE, Office of Science, <http://www.science.doe.gov>

Additional References:

- a. Gerard, David and Wilson, Elizabeth J., Carbon Capture and Sequestration: Integrating Technology, Monitoring and Regulation, Blackwell Publishing, 2007
- b. Gielen, Dolf and Podkański, Jacek, Prospects for CO₂ capture and storage, International Energy Agency, 2004
- c. Anderson, Roger. "The Distributed-Storage Generation 'Smart' Electric Grid of the Future" Workshop Proceedings of 'The 10-50 Solution: Technologies and Policies for a Low-Carbon Future.'
- d. Broder, John. "Bush Signs Broad Energy Bill." The New York Times 19 Dec. 2007.
- e. "Can the U.S. Electric Grid Take Another Hot Summer?" Hearing Before the Subcommittee on Energy & Resources 109th Congress, 2nd Session, July 12, 2006.
- f. Vattenfall http://www.vattenfall.com/www/vf_com/vf_com/365787ourxc/index.jsp
- g. Intergovernmental Panel on Climate Change <http://www.ipcc.ch/>